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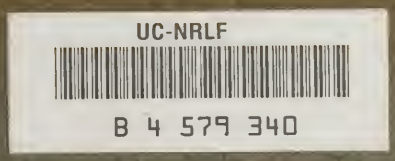

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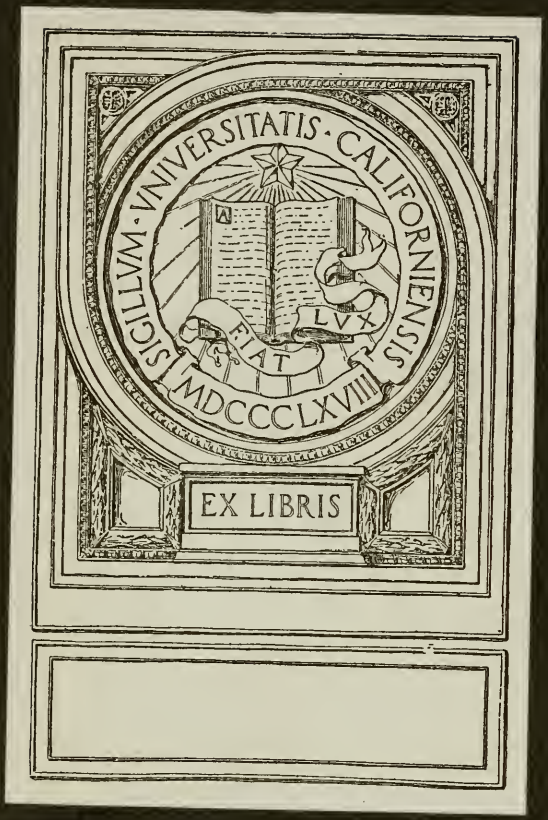
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SEAPORT AND RIVERPORT TERMINAL DESIGN

FOR

Rivers with high flood stages or with hight banks

BY

H. McL. HARDING

Terminal Engineer of the City of Natchez, Miss.

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Variations in the water levels at cities. — On most of the rivers of the United States, there are great variations in the water levels during different periods of the year. Often there are two flood stages, one in the early winter and the other in the spring.

This condition is especially true to the Mississippi River, its tributaries and other rivers emptying into the Gulf. At Natchez in the Mississippi the variation is from — 5 ft. to + 54 ft., a variation of 59 feet. The usual low water is however + 5 ft., and the high water + 45 ft., making an annual variation of 40 ft., though as above stated, this is often greater.

At New Orleans, the high water may be taken at + 21 ft., at Baton Rouge at + 40 ft. Above New Orleans on the Mississippi River the following few figures will indicate certain high water stages at various cities. Cairo, Ill., + 54 ft.; Memphis, Tenn., + 44 ft.; Helena, Ark., + 54.20; Greenville, Miss., + 50.50; Vicksburg, + 52.43. On some of the tributaries as on the Ohio River as at Cincinnati the flood stage has been above + 71 ft., while at Kansas City on the Missouri + 31 is regarded as a high flood stage. At Pittsburgh there are similar floods. There are always flood stages annually even though the maximum and minimum may vary from the above figures from year to year. As there is, however, the certainty of flood stages, there are

required special plans and devices in terminal design for protection and efficient operation. This annual recurrence of high water often continues for several weeks. During the highest stages the discharging and loading of vessels are often discontinued.

In other countries there are even greater water level variations in certain rivers.

Yangtse River in China. — The most important river in China is the Yangtse River. It is 3,200 miles in length and drains an area of 700,600 square miles which has a population of 200,000,000. Its discharge is at times 3,530,000 cu. ft. per second, and its speed of flow is between 3 and 4 knots per hour. The maximum discharge of the Mississippi is about 2,000,000 cu. ft. per second. In the upper reaches of this Chinese river there have been 96 feet between high and low water.

At the lower stretches of the Yangtse there is a variation of about 30 ft.

Freighters of 4,000 tons travel on the Yangtse between Shanghai and Hankow and the average is from 2,000 to 2,500 tons. In some cases there have been ocean ships of 6,000 tons traversing this stretch of the river.

The traffic on the inland waters of the world has been said to have a tonnage equal to that of the ocean traffic.

There seems to be an impression that high flood stages constitute an insurmontable difficulty in securing speed and economy in freight transference and are a detriment to river navigation.

European Rivers. — On the British Coast in the British Channel at Chepstow, the high water occasionnally culminates in a height variation in water levels of 60 ft.

The following list of tides is instructive:

GREAT BRITAIN		FRANCE	
Barry	37 1/2 ft.	Boulogne . . .	26 ft.
Bristol	33 »	Dieppe. . . .	27 1/2 »
Cardiff. . . .	36 1/2 »	Havre	22 »
Liverpool. . .	34 »		
Newport . . .	38 »		

At many foreign ports wet docks have been constructed but at a greater expense than would be permissible at river terminals along the Mississippi at the present time.

Maximum height of quay levels. — In the determination of commercial designs for terminals for such rivers consideration has been given whether provision must be made in the design for the highest peak of the high water which may not be reached until after intervals of years.

There is often valuable merchandise on the quays and in the sheds, the flooding of which by the river might cause loss, which in some cases would amount to several millions of dollars. This condition cannot be ignored, and therefore the elevation of the shed floor should be above the highest known flood stage by from two to three feet.

If the maximum flood stage is 53 feet, then the quay level elevation may be 56 feet.

These floods indicate their coming far up the river among the hills. At the important river port towns there is generally at least one or two days notice that the flood waters are « on the way ». From this it has been urged that there will be sufficient time to remove freight to a place of safety before the high water reaches the city. However, from losses that have occurred, this does not seem to work out well in practice, although in most of the newspapers of these river cities there are published daily the river elevations at the various cities along the river, so much importance has been given to the rise and fall of the rivers. It is necessary, therefore, to consider this highest water condition in the designing the terminal.

Two quay levels. — Often there are high bluffs located near the frontage with a gradual or steep ascent and then in another case there is a broad plain which extends for a considerable distance away from the edge of the river, and is flooded at the highest stages. At certain locations, where there are not great variations in the river elevations, there are level areas and high lands to the rear, or the high land rises abruptly from the river.

These conditions prevail at Natchez, Miss. The bank directly in front of the city ascends first at an easy slope, and then to high

bluffs over 180 feet in height. To the south of the city is a broad plain which is only just flooded at the highest water.

Different designs for local and commerce terminals. — It will be seen that it may be necessary to have different designs for terminal development along the same frontage. The having of distinct designs is not, however, wholly due to the physical characteristics of the shore, but partially to economic or commercial reasons.

This is because there are required two separate terminals with two different functions designated as local and through terminals.

The river frontage directly opposite the business centers of the city should be utilized for the local inbound and outbound traffic, and is therefore designated as the local terminal section and is usually divided into local terminal barge units each of 300 feet frontage.

Of all the freight of the city of Natchez probably at the beginning 20 % will be local freight directly pertaining to Natchez and its immediate hinterland, and 80 % will be through or commerce freight from or to remoter sections of the country.

Less investment in local terminals than in commerce terminals. — The length of each of the commerce terminals units will be double that of the local unit or 600 feet. Not so capital should be invested in local terminals at which will be transferred so small a proportion of the total tonnage in order that the terminal may earn a net income. Not only, therefore, must the length of the terminal unit be less, but the cost of works and facilities per linear foot must be less. Hence the difference in design. An examination of that portion of the waterfront of the City of Natchez applicable for local terminals shows that there is a narrow, steep inclined bank extending from about 0 elevation to approximately 55 feet, then a level area some 300 feet in width and then the steep bluffs which are in some places almost vertical.

Freight movements. — Rail or dray approaches to the terminal should be designed separately from the quay. — It is always a part of wisdom to treat any appliances for transferring freight between the highest elevation, on the top of the bluffs and the

low level quay of the terminal unit, and between this lower quay and the vessel separately; and then where necessary to connect the two installations, but not combine the two in one original design. By designing the local terminal unit for its legitimate purpose of discharging and loading barges and the temporary holding in the shed of freight, that is, for transferring cargoes between the vessels and shore and then for assorting, distributing or tiering for further movements by vessel which is transshipping, or by car which is transferring, or by drays which is drayage, the best results are attained.

Incline railways should be regarded as approaches. — An incline or elevator movement may follow those of the terminal proper. It should be regarded as a terminal approach whether horizontal or inclined.

Barges, which will be the type of freight vessel which will chiefly berth at local terminals, also have an influence on the design.

Further successful development of waterway transportation terminals depends obviously upon the nature of the river craft to be constructed. Experience indicates that the modern barge with hatchways which can be opened over every portion of the barge, so that there can be a free vertical movement of the freight from or to every place in the barge, is the evident solution of the problem of quick operation. Such is the construction of barges in France which carry the freight in the hold and not on the deck. Such a barge is the practical carrier at the minimum cost of construction and which gives rapidity of freight operations.

Terminals and carriers should be standardized. — Like the railway with its rolling stock of cars and the locomotive, the waterway with its barges and power boats should have approximately standard dimensions with suitable terminals and terminal facilities, with the necessary railway and roadway approaches.

A rail incline as in one case at Natchez extending to an elevation of nearly two hundred feet above o datum elevation is only a railway approach on an exceedingly steep grade and should be so regarded. If there is this separation, the designing becomes more simple.

As only about ten to twenty per cent of the total freight of the port will be elevated up this incline, the problem of this incline approach becomes less difficult of solution.

Barges should not be delayed by inclined railways. — It is better, however, not to discharge freight directly from barges upon the cars on the incline or from the cars to barges, as this will defeat the all important function of terminals, namely, to attain the greatest possible speed of transference, to remove all congestion points and to reduce the barge delay to the minimum.

The freight should be discharged upon the quays or slopes and the barge be loaded from the quays, and the barge should not be delayed for any secondary movement, as up or down the inclines.

The bluffs of great height as far as the detention of the barges is concerned are not a detention factor, as this secondary movement may occur after the barge has departed. It is therefore important in designing to regard inclines as approaches.

Intermediate quay. — There is, however, an annual average variation of the stages of the river in front of the city of Natchez of about 40 feet, with a maximum of about 59 feet, but the average lift of the cargoes above the barges during the whole year is about twenty feet. The average height of lift at local terminals is not so great as with great freighters at ocean terminals, nor is the maximum lenght of crane rope any greater.

The water elevations may vary from year to year, but the figures as given are approximately correct.

To assist in the designing of the local terminals, there may first be considered the movements of the inbound freight.

As to the discharging the vessels the chief object is to remove this freight from the barge as rapidly as possible and in the depositing each draft on the quay to assort, distribute and tier it for the next movement, as it is not to be kept on the quay or in the shed more than from thirty-six to seventy-two hours.

Some of this freight is to be transshipped to other vessels, some to be transferred to cars and some for the incline or for drays.

Transshipment freight. — The average height of the river has its influence as to the time and place of deposition. Assuming

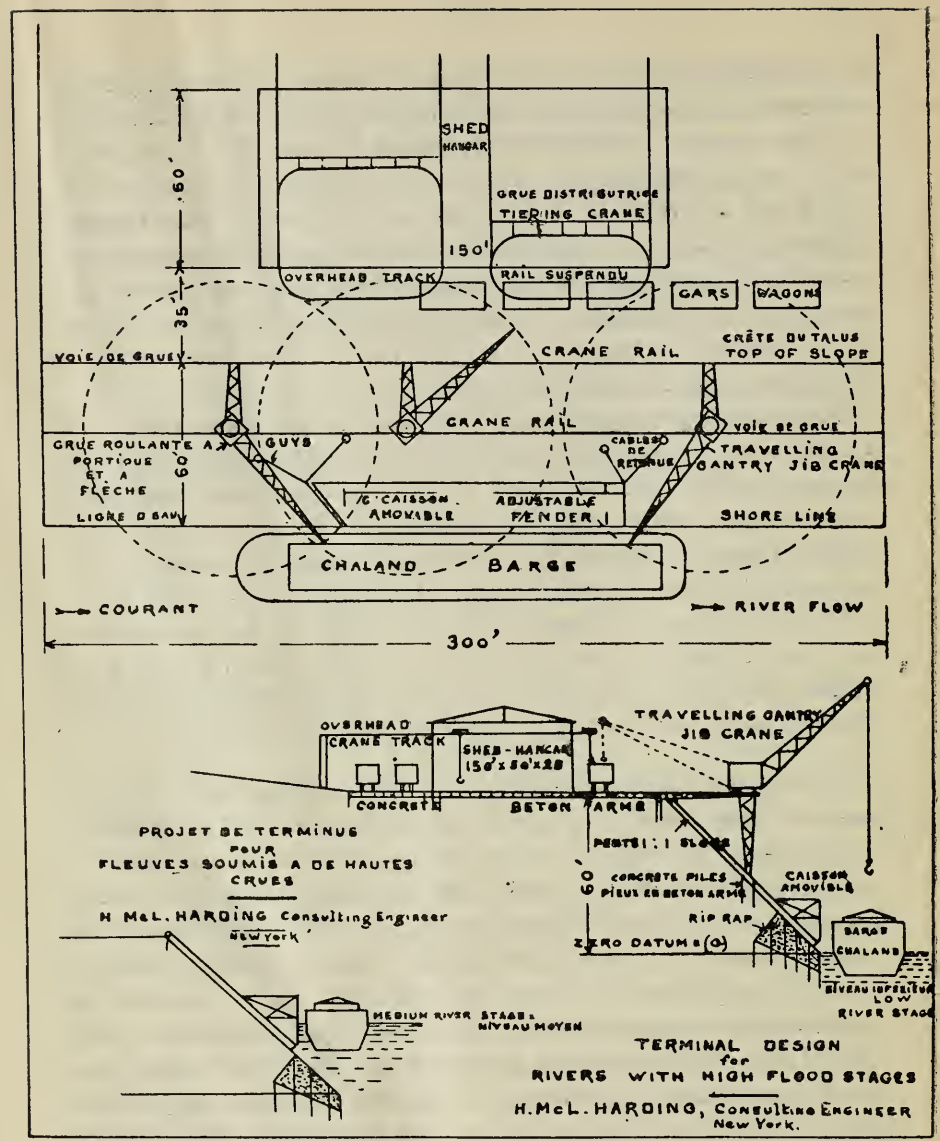
for example that the river is at an elevation of about eighteen feet and a considerable portion of the cargo is to be transshipped to other vessels, it would be preferable to place it on a slope or on a narrow level strip at an elevation of twenty to twenty-five feet above the river, as the freight will be quickly transshipped to another vessel or vessels and it must be deposited and assorted somewhere according to the marks for the different vessels into which it is to be loaded. In cases where the foreshore is narrow, it is generally necessary, from the construction standpoint, to raise the freight to the quay level.

As the average height of water is below twenty feet during most of the year, it would be well to have a place for local transshipment freight on some such slope or level at about twenty-five feet elevation where there is sufficient width of the foreshore. There therefore should be a slope or space for freight at an elevation of about twenty-five feet the lenght of the quay.

This elevation of twenty-five feet would not be usable when the river is above twenty-five feet, so there should be the quay constructed at an elevation above the highest flood stage which may be taken at Natchez to be fifty-seven to sixty feet.

No manual labor rehandling. — Rehandling especially by manual labor must be avoided. Therefore it must be possible, after taking the freight from the barges by cranes and it has been mechanically assorted, to deliver by machinery from the different elevations to the cars, to sheds, to drays or to the inclines. This operation must not delay the barges. The machinery must lift from the barge and deliver to either of the levels. Likewise the same machinery must take the outbound freight from drays, from cars, from either elevations and from the shed, and deliver into the barges without rehandling. Often the outbound freight does not require any assorting, but may be transferred directly to the barge.

The following plans, designs and elevations will indicate how these inbound and outbound movements can be performed rapidly, economically and easily, with such a reasonable cost for construction that it will be possible to obtain a net income from the investment. There will not be necessary any high concrete wall, or any wharf boat, but only a revetted bank with cranes and an adjustable fender.



At seaport or riverport terminals with high flood stages or high banks, there are often physical conditions for which three or more designs may be required. The diagram given above illustrates only one condition, that is, where the foreshore is steep and narrow. It will be noted that there is no wharf boat or floating wharf, no high wall, and the investment for shore slope improvements is chiefly for a superior type of revetment.

There are other designs not here given where the foreshore is steep and broad, or where the slope of the foreshore is gradual and broad as at existing levees. For these and combinations or modifications, designs, have been prepared where necessary and with no reduction of the prism of the river.

To attain rapid and economical terminal operation, there must be direct transference without rehandling, either discharging or loading, between vessels and car, dray, shed or quay above the highest flood stage.

The initial investment for shore development must be small.

There are opposite the civic centers of many river cities, paved levees and the problem to which reference will be made later, often is to utilize these paved slopes as they exist so that they can be of immediate service. The construction of new levees but not levee-quays for terminals generally follows the following rules when permissible by local physical conditions.

Standard levels. — The top of the levee to be 3 feet above the highest floot stage with a section having a crown of 8 feet wide, a river slope of 1 on 3 and land slope of 1 on 3 to 8 feet below the crown and thence a banquette of varying widths from 20 to 40 feet with a slope of 1 on 20, depending upon the location. There are many existing levees which it is desired would be improved at an early date.

The levee-quay. — A levee-quay for utilizing the levee for temporarily holding freight should be at a slope of 1 on 5 to 1 on 7. These figures pertain to the Mississippi River and its tributaries.

Whatever may be the height or width of the levee, where terminals are necessary, it is generally desirable that by a proper design of slopes and levels the existing levee be so improved that freight can be transferred and handled with rapidity and economy.

Provision for existing wharf boats and river boats. — It is difficult to understand why a portion of the existing levee should not be thus improved, so as to be equal to the most modern terminal in speed, economy and ease of discharging and loading the barges; also in the assorting, distributing and tiering, and the securing water and rail coordination, and at a smaller investment than by selecting other locations. Only a part of the levee need be so improved at first, and even here and elsewhere there would be ample frontage for the existing wharf boats and the older types of river boats. There would remain all the usefulness of the present levees and in addition all the advantages claimed by the most earnest advocates of modern terminals. These paved levee slopes were located where they would be most accessible for the local freight of the city.

Among advantages utilizing these existing levees may be named a few:

1st. — Discharging and loading barges by mechanical appliances adapted to the existing levees;

2nd. — No rehandling by manual labor;

3rd. — Assorting, distributing and tiering by machinery;

4th. — Improved freight lifting from the barge by mechanical power with the freight directly conveyed and placed upon the levee; from the barge deposited upon an elevation above the highest flood stage or upon open cars, including all movements between the barges and all the terminal elements. If there are warehouses located at the rear of the sheds, it would be possible to convey and place within the warehouse and into the second or third story, thus conveying above the street traffic.

All mechanical freight movements possible. — In addition to the above, freight can be taken from the slopes and transshipped to other vessels or from a lower position of the levee to a higher portion of the levee, to cars in front of or to the rear of the sheds, to drays, to the warehouse and to the street in front of the warehouse. Bulk freight as coal, ore, sand or rock can be heaped upon the levee-quay in piles, and these piles or material can be transshipped to other vessels or placed upon coal cars, sand or ore cars, or piled upon the upper level above the highest flood stage of the river. This inbound freight can be distributed and tiered within the shed, having been assorted in the conveying.

Inbound freight. — Each of these movements is a direct movement to or from the barge and the point of deposition and several drafts of separate marks may be hoisted and conveyed in one trip and by one man only.

Outbound freight. — Outbound freight can be taken from warehouse to the shed which is above possible floods to and upon the levee, and there tiered or taken directly to the barge and placed within the barge.

The movements have thus been enumerated at length to show that all movements of the freight can be performed mechanically.

With barges that have hatches that can be opened anywhere over the whole cargo, freight can be placed anywhere within the barge, without any horizontal dragging, pulling or lifting by manual labor.

Freight can be lifted from the floor space within the shed or deposited on the floor area of the shed.

Improvement of river banks. — All movements desired at a terminal can be performed in connection with existing levees. If there are no levees in front of a city, and there is a bank with a moderate slope, and an estimated moderate tonnage of freight, this can also be developed into a terminal having all modern facilities.

Variation in designs. — The material of which the bank is composed and the layers of subsoil from its high water levels to the bed of the channel influence greatly the character of the design.

The geology of the country where the terminal is to be located should receive careful study especially to secure permanence of the sub-structure. The following is given as an illustration.

In the Natchez district extending from the middle of the Mississippi River below the channel, and beneath the river bank, beneath the bluff and the city and extending some six or more miles eastwardly, is a layer of indurated blueish gray clay in some places over eighty feet in thickness and impervious to water. This clay is little affected by erosion.

The top of this layer along the river bank on the foreshore is about thirteen feet above the o datum of Natchez. Its hardness while permitting the driving of piles, gives to them a great sustaining power. Above this clay is a layer of sand and gravel, in some places cemented together for a thickness of twelve to eighteen inches with the iron from flowing springs, but this also will permit the forcing through of piles, though steel shoes may be required.

With such a sub-soil layer dredged to the correct angle weighted with tons of rip-rap with a surface angle of 45 degrees dumped between the piles there will be obtained a wonderful permanence of construction.

Where this blue clay is at the bottom of the river, the depth, as for example at the o datum, there is little variation in depth as per the Government record for a number of years past.

It is, therefore, recommended that if possible along these rivers layers of some hard material be found, if it exists at a reasonable depth, and it be given full consideration in the terminal design. There is an impression that along the Mississippi River there is an almost unfathomed depth of soft, loose material.

It is true that there is little rock, but there is much hard clay, sand and coarser materials especially near the waterfronts of cities along the Mississippi River the strata of which may be found excellent for the foundation of riverfront terminals.

No permanence can be assured if there are subsoil streams, springs or even swamp seepage below the terminal site. Such, however, can be drained and often with comparatively little expense.

In all cases there should be borings not less than fifty feet centers over the waterfront terminal areas.

It is stated by eminent Government engineers that a bed of blue clay extends from Cairo along the river to within fifty miles of the Gulf.

At Clear Creek, lying to the east of the City of Natchez, « pot holes » have been formed in this clay by stones rolling around in a cavity, the same as the pot holes in the granite of New Hampshire. This illustrated the impermeability of the clay to water, and its considerable resistence to erosion. The important fact is, however, that this clay is impervious to water. This clay comes nearer to the surface of the soil to the east of Natchez and dips downward to the west as it approaches the river. From attrition of particles of gravel and sand it has evidently been somewhat worn away.

The above facts will be found useful in the designs of most Mississippi river terminals.

Consideration must be given to the fact that a terminal to be a commercial success must be a freight terminal, not chiefly for passengers, and that there must be a tonnage which will amount to thousands of tons annually.

A river terminal not merely a wharf. — The river terminal of today along the Mississippi and its tributaries is not a decaying wooden wharf or a worm-eaten pile cluster, the fate of which is the burning, or even the river bank to which river boats can tie up to deliver and receive a few tons of freight, as in the past, but consists of permanent, indestructable concrete or a submerged, eversaturated, non-decaying pile structure, fire proof, concreted quays, for miscellaneous cargoes with paved slopes and with quays above the flood stages. There should be many railway tracks parallel to the river. In addition, there must be steel sheds, high studded and enclosed to protect cargoes for inclement weather or thefts, and concrete warehouses for various commodities, many stories for long storage, the whole representing, however, a paying investment.

Through such a terminal must pass a sufficiently large tonnage, rapidly and economically, to make the terminal « pay ». There are many features about a modern terminal which must not be ignored if satisfactory results are to be attained.

The ancient wharf boat, while fulfilling its purpose in the good old days of small tonnage, like the early river boats, lacks three important features: the first, the inability to transfer and handle sufficient tonnage of freight per annum; second, lack of direct water and rail coordination; third, the freight transference and handling of a large tonnage would be far too slow and expensive. It is evident that there would be too much rehandling to be a commercial success.

The lifting between the barge and the quay level to the top of the bank must be performed mechanically to secure speed of transference and economy of operation.

Terminal principles. — There are, however, variations in the local terminal designs, depending upon the width of the foreshore. Certain terminal principles are, however, applicable to both designs and these may be condensed as follows:

First:— In addition to through or commerce terminals, often at quite a distance from the civic center, a city should have local terminals, that is, terminals chiefly for freight which originates in or is to be consumed in this city or vicinity.

Second:— Such local terminals should be located as near the business center of the city as is commercially possible.

Third:— Such local terminals should be wholly owned, operated and controlled by the city.

Fourth:— It is highly desirable that the time of construction per terminal unit should be as short as possible.

Fifth:— The investment in each terminal unit should be no more than it is possible to earn from it, a fair rate of interest, above all expenses for operation and maintenance and to provide for amortization.

Sixth:— There must be the greatest speed of transference and handling freight.

Seventh:— Mechanical operation and direct coordination between water and rail are essential to secure speed and economy without congestion.

At a comparatively small investment it is now possible, due to terminal engineering, to utilize these existing sloping levee wharves along the waterfront of a city almost without change, so as to obtain all the desirable features of the modern river terminals such as the utmost speed and economy of operation, both of transference and handling by external and internal machinery, also water and rail coordination, the installation of steel transit sheds, no manual rehandling, direct mechanical loading and discharging barges, all at a far less time than is usually required for construction, and at a much less than the usual investment. In addition, there need be no reduction of the prism of the river.

One-half of the existing river frontage could be exclusively reserved for the present type of river boat, although the whole levee frontage could be utilized by them as at present.

The above means much to river cities and is what has been long desired. It is the result of experience and involves no new types of machinery.

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